

times decreased significantly between 10 and 15 cm/s (both tests,  $p < 0.01$ ), but higher velocity ( $> 15$  cm/s) had no significant effect on either response (all tests,  $p > 0.1$ ). At velocity above 10 cm/s, 50% of delta smelt became impinged within 6-49 minutes and fatigued within 11-64 minutes.

Results of these studies show that, although delta smelt achieved and sustained moderately high maximum swimming velocities (*ie*,  $U_{crit}$ ), their sustained swimming performance was highly variable and generally poor. Most fish were unable to sustain swimming at velocities above 10 cm/s for more than a few minutes without becoming impinged on the screen in the flume. We believe there are several reasons for this poor performance. First, sensitive delta smelt responded poorly to confinement in the swimming flume. Although we believe the maximum performance responses we measured (*ie*,  $U_{crit}$  values and high endurance times) are probably relatively accurate measures of the maximal performance capacity of this fish, the high failure rates (*ie*, fish unable to swim adequately), high rates of impingement at submaximal velocities, and low endurance and Imp1 times at low to moderate velocities probably reflect stress and inability of the fish to express appropriate behavioral responses to the current, such as escape behavior, in the confined flume. Furthermore, a laminar flow swimming flume is a poor simulation of complex flow regimes typical near water diversions (Pearce and Lee 1991). Second, behavioral observations of undisturbed, minimally confined, spontaneously active fish indicate that, unlike many other fishes for which these types of studies have been done (*eg*, salmonids), delta smelt are unsteady, slow swimmers, rarely swimming faster than 10 cm/s

| (cm/s)<br>(n)      | Velocity       |              |             |             |             |             |
|--------------------|----------------|--------------|-------------|-------------|-------------|-------------|
|                    | 5<br>(10)      | 10<br>(16)   | 15<br>(15)  | 20<br>(20)  | 25<br>(15)  | 30<br>(7)   |
| Endurance<br>(min) | 360<br>254-360 | 360<br>3-360 | 64<br>2-360 | 51<br>2-360 | 50<br>1-360 | 11<br>2-360 |
| Imp1<br>(min)      | 292<br>5-360   | 144<br>2-360 | 16<br>1-196 | 16<br>2-200 | 49<br>1-360 | 6<br>2-360  |

(Swanson and Cech 1995). Third, delta smelt exhibit a velocity-dependent change in swimming mode, or gait. At low velocities ( $\leq 10$  cm/s) the fish swim using a "stroke and glide" mode, alternately stroking and coasting through the water. At velocities above 15 cm/s, the fish shift gaits to swim by stroking continuously. The velocity at which the fish change gaits, between 10 and 15 cm/s, appears to be very stressful to delta smelt, as evidenced by  $U_{imp1}$  and the dramatic decrease in endurance and Imp1 times at these velocities. Analyses of the swimming kinematics of delta smelt (to be reported in a subsequent *Newsletter* article) confirm this change in swimming behavior.

Because of these factors, we do not recommend direct application of these results to develop approach velocity criteria for delta smelt. Such use may seriously misinterpret the true performance of the fish in flow regimes like those near diversions. We believe another approach is necessary, using methods and equipment that more accurately simulate diversion flow regimes and provide the fish with adequate space in which to express appropriate behaviors. We are currently developing this project in collaboration with the UC-Davis Hydraulics Laboratory and the Department of Water Resources, and we look forward to reporting our results in this *Newsletter*.

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### Delta Outflow

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During April and May, the Delta Outflow Index averaged about 36,000 cubic feet per second. Outflow peaked to about 99,000 cubic feet per second due to a major late-season storm in the latter part of May. Combined SWP/CVP pumping for April and May averaged about 6,000 cubic feet per second. Around June 12, inflow into Clifton Court Forebay was stopped to accommodate herbicide treatment. An introduced species, *Egreria densa*, growing in the forebay is causing problems at the fish salvage facilities, as well as at the pumps.

